CMARP Delta Levees Work Team
Delta Levee System Integrity Program Monitoring Components
Draft Report

10/1/98

I. MONITORING OBJECTIVES

The fundamental objective of the overall Delta Levee System Integrity Program is to "reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching of Delta levees." The specific elements of the Delta Levee System Integrity Program are discussed fully in the CALFED Long-Term Levee Protection Plan and include:

1. **Base Level Protection Plan**: Target – Improve and maintain Delta levees to the PL 84-99 standard.

2. **Special Improvement Projects**: Target - Improve and maintain levees at key Delta locations to a level commensurate with the benefits protected.

3. **Subsidence Control Plan**: Target – Reduce or eliminate risk to levee integrity from subsidence.

4. **Emergency Management and Response Plan**: Target – Enhance existing emergency management response capabilities in order to protect critical Delta resources in the event of a disaster.

5. **Seismic Risk Assessment**: Target – identify risk to Delta levees from seismic events and develop recommendations to reduce levee vulnerability and improve their seismic stability.

Each of the monitoring elements selected by the CMARP Levees Technical Team will support a determination of whether the above five program elements are achieved.

Additionally, monitoring elements must be developed to insure that environmental mitigation for impacts resulting from implementation of any of the above five elements is successful.

Specific monitoring objectives can be separated into two categories based on physical and biological indicators.

Levee Monitoring Objectives that Contain Physical Properties -

1. Establish that a base level of flood protection for Delta levees at the PL 84-99 standard, or higher as necessary, has been achieved and maintained.

2. Establish that special levee improvements have been achieved and maintained in key Delta locations to a level commensurate with the benefits which the levees protect.

3. Establish that the risk to levee stability from subsidence has been reduced.

4. Establish that an emergency management and response plan has been adopted and maintained that has the capability to protect critical Delta resources in the event of a disaster.

5. Quantify Delta levee seismic risk and compare it to other failure modes.

Levee Monitoring Objectives that Contains Biological Properties–

1. Establish that impacts from any construction/management action associated with achieving the overall objectives of the Delta Levee System Integrity Program are mitigated as appropriate. Construction/management actions include:

   A. Levee improvements or maintenance
   B. Excavation of material at borrow sites and its transport to the construction sites
   C. Channel dredging for fill material
   D. Placement of dredge reuse material

II. CONCEPTUAL MODEL AND/OR LISTING OF HYPOTHESES AND ASSUMPTIONS OF THE SYSTEM

Common Survey Standards:

Monitoring plans for each of the four Delta Levee System Integrity Program elements are directly or indirectly dependent on accurate vertical and horizontal data. A common coordinate system for quantifying and mapping features that are tied to vertical and horizontal position in the Delta is critical in determining levee standard compliance, and the effects of subsidence and seismic activity. Specifically, minimum survey control standards are needed to develop a network of vertical and horizontal control points in the Delta.

Without this common survey standard, true elevations and horizontal positions for Delta levees cannot be known, thereby leading to a false sense of confidence in survey data and flood protection. Appendix F contains specific recommended methodology for establishing the needed common survey standards for the Delta.

Models and Assumptions of the Levee System:

The Delta Levees component of CMARP does not have a classic, analytical model that governs levee condition or behavior. However, there are several specific factors which can be measured relative to each of the five Delta Levee System Integrity Program elements.

1. Base Level Protection Plan and Special Improvement Projects

Levees may be built to various standards depending on the level of flood protection desired. It is the goal of the Long-Term Levee Protection Plan to eventually implement Public Law 84-99 (PL-99) performance criteria for non-project levees in the Delta (See Attachment A to Appendix A). It is also envisioned that higher flood protection standards may be desirable at key Delta locations to a level commensurate with the benefits protected. Most Federal project levees in the Delta already meet the PL-99 standard. PL-99 criteria include specific cross section dimensions that must be achieved and maintained. The geometry of the levee will significantly influence how the levee responds to geotechnical and hydraulic forces in the system.

Once a levee is built to a desired standard for flood protection, it is imperative that it be maintained to resist the many forces that work to undermine its integrity. The first step in levee maintenance is levee inspection. Levee inspection detects various levee problems before they become critical threats. Levee inspections evaluate the condition of the levee crown road, the condition and inspectibility of the land and water sides of the levee, the presence of levee encroachments and evidence of animal burrowing damage. Once a problem is detected with any part of the levee, maintenance should proceed.

Appendix A describes the specific monitoring plan for these elements. (In some cases, the Special Improvement Projects element may include monitoring from other elements such as the Subsidence Control element.)

2. Subsidence Control Plan

Subsidence has substantially contributed to the Delta islands current condition of relatively tall levees protecting interiors below sea level. Recently, however, the risk to levee integrity from subsidence has diminished. Land management and levee maintenance practices have improved, and subsidence rates have decreased. In addition, a zone of influence (ZOI) extends from the levee crest to some distance inland, beyond which subsidence will not affect levee integrity. Outside the ZOI, interior island subsidence will not affect levee stability. However, subsidence within the ZOI may potentially impact levee integrity. The ZOI for a reach of levee can be determined using site-specific data. The Subsidence Control element will include monitoring to determine if levee integrity may be compromised due to subsidence.

Appendix B describes the specific monitoring plan for this element.

3. Emergency Management and Response Plan

Delta levees have a history of failure, bringing the devastating effects of flooding to various land uses. Many of these levee failures occurred without warning and were not tied to a single stressful event (storm, etc.). Proper emergency response activities can be a cost-effective supplement for levee protection; however, they cannot substitute for a proper maintenance and repair program.

Delta levees protect approximately 527,300 acres of farmland, 67,000 acres of urban development, and 82,800 acres of native habitat. The Delta's channels and adjacent banks provide habitat for fish and wildlife, accommodate shipping, provide local water supply, protect infrastructure and convey water to over 20 million Californians. Most of the protected land is below sea level and therefore emergency response actions are unusually important requiring prompt response and action. A levee failure can endanger public safety and inundate thousands of acres of farmland up to 20 feet in depth, requiring a costly process to reclaim the island. Also, such an event can cause significant salinity intrusion degrading Delta habitat and impeding the operations of major State and Federal water delivery systems.

An effective emergency response system is critical to the long-term protection of the Delta. The emergency response system must be monitored to insure that it adapts as conditions and needs change in the Delta.

Appendix C describes the specific monitoring plan for this element.

4. Seismic Risk Assessment

Earthquakes can cause levees to fail by slumping or liquefaction of underlying soils. To date, there have been no known Delta levee failures or island inundations as a result of seismic events. However, there are several active faults located sufficiently close to the Delta to present a threat to Delta levees.

In 1992, The Department of Water Resources, Division of Engineering completed the "Phase I Report, Seismic Stability Evaluation of the Sacramento-San Joaquin Delta Levees." Subsequently, the Department took several actions to reduce some of the unknowns that influence the evaluation of levee stability during earthquake shaking.

Assessments by the United States Geological Survey concluded that there is a high probability that a large magnitude earthquake will occur in the San Francisco area within the next 30 years. This conclusion together with the 1989 Loma Prieta Earthquake has increased concerns for the seismic stability of levees protecting islands in the Sacramento-San Joaquin Delta.

Concern exists because the islands in the Delta are generally 10 to 15 feet below sea level and the levees are usually composed of uncompacted sands and silts. The levees are built without engineering design and/or good construction methods. Levees composed of such materials may experience liquefaction and damage during moderate to strong earthquakes. The inundation of one or more islands in the Delta during a period of low outflow could result in saline water from the San Francisco Bay being drawn into the Delta. This could significantly impact the export of water as well as numerous other public facilities and resources that afford a wide range of benefits to the people of California.

Generally, foundation soils in the Delta consist of varying amounts of organic soils. Knowledge of the dynamic behavior of organic soils in the Delta is essential for the determination of ground response to earthquake shaking.

Appendix D describes the specific monitoring plan for this element.

Environmental Issues

5. Habitat Mitigation:

The Long Term Levee Protection Program includes measures to control subsidence, and reconstruct, relocate and maintain levees in the Delta. These measures will likely require significant amounts of fill material to be extracted from sources within and around the Delta, including dredging from Delta channels, and their placement on and around levees. This work may result in significant impacts to terrestrial and aquatic resources. Monitoring and research will help quantify these impacts and the performance of any necessary compensation.

Appendix E describes the specific monitoring plan for this element.

III. MONITORING AND RESEARCH ELEMENTS

Following is a list of monitoring elements that the CMARP Levees Technical Team recommends be included in the overall assessment of levee integrity and durability pursuant to the Delta Levee System Integrity Program. Each of these monitoring elements, including their respective research components, is described in detail in Appendices A through F.

1. Levee Standard Monitoring Plan: Appendix A
2. Subsidence Control Monitoring Plan: Appendix B
3. Emergency Management and Response Monitoring Plan: Appendix C

4. Seismic Risk Assessment Monitoring Plan: Appendix D
5. Habitat Mitigation Monitoring Plan: Appendix E
6. Common Survey Standard: Appendix F

Each of these elements is generally characterized above in Section II of this report.

IV. LINKAGES

There are many areas of overlap between monitoring and research proposed by the CMARP Levee Work Team and other existing programs, CMARP work teams or components of the CALFED Program.

A great deal of CALFED Program work will require horizontal and vertical control. A single base map/control is critical. Horizontal and vertical datum will be needed by the CALFED storage and conveyance and ecosystem restoration program elements in addition to the Levee Program.

Many proposed components in the "Levee Standard Monitoring Plan," Appendix A, are already being monitored by the DWR Central District as part of its administration of the Delta Levee Maintenance Subventions and Special Flood Control Projects Programs. The Subventions Program Maintenance Criteria presently conforms to the 1986 Flood Hazard Mitigation Plan for the Delta. Many nonproject "local" levees in the Delta have adopted the State's Short Term Levee Rehabilitation Plan standard found in the Flood Hazard Mitigation Plan for the Delta (1986). In order to continue eligibility for FEMA disaster assistance funding these districts have submitted profiles and cross sections documenting minimum geometry and levee profiles to FEMA, the State Office of Emergency Services and the Delta Levee Maintenance Program. Requirements for compliance with the HMP are summarized below:

(1) Levee Profile Program participants are required to make a profile of the levee crown not less than every fifth year, of more often if determined necessary by District Board necessary (such as after severe storms).

(2) Levee Cross Section DWR retains copies of existing cross sections documenting that levees meet minimum HMP cross section criteria. When districts have brought their levees into compliance with HMP they are required to update cross sections, at intervals no greater than 500 feet, in the areas where rehabilitation projects are performed. Copies of this information has also been submitted to FEMA. + DFG under AB360.

(3) Annual Levee Maintenance Inspection DWR annually inspects nonproject levees in the Delta in accordance with Water Code Section 12989 of the Water Code and the 1986 Flood Hazard Mitigation Plan. The review includes the following levee maintenance activities:

- Vegetation removal, Road surface maintenance, Roadway crown grading, and Gate repair on the levee crown
- Vegetation removal, Hazard tree removal, Mature tree trimming, Slipouts, Erosion, Cracking, and Subsidence on the land side levee slopes
- Vegetation removal, Revetment slippage, Slipouts, Erosion, Cracking, and Subsidence of the water side levee slopes
- Control of encroachments that affect levee integrity
- Control of rodents that affect levee integrity

In addition, the U.S. Army Corps of Engineers conducts continuing eligibility inspections for those levees that have obtained PL-99 certification. These inspections occur approximately every two years.

The bathymetric data that is proposed in the "Levee Standard Monitoring Plan," Appendix A, to monitor for sedimentation and scour will also be needed by the storage and conveyance Program of CALFED. As well, the Ecosystem Restoration Program will require information on sedimentation and scour as it impacts benthic habitat and other ecosystem elements.

Research on sediment toxicity and characterization data that is proposed in the "Levee Standard Monitoring Plan," Appendix A, is also of concern to the Ecosystem Restoration Plan. The ERP goals include the creation of shallow water habitat which may involve dredged material. This research is also of concern to the Water Quality Program to quantify water quality impacts from dredge activities and placement of dredged materials.

Some of the data collection proposed in the "Subsidence Control Monitoring Plan," Appendix B is currently collected by other agencies. The Natural Resources Conservation Service obtains soil property data for publication and some of this information may be applicable to the Plan. The "Subsidence Control Monitoring Plan" also calls for sea-level data which is collected by NOAA, EPA, and USGS.

Some of the proposed monitoring in the "Seismic Risk Assessment Monitoring Plan," Appendix D section is currently being performed as part of the DWR DOE seismic studies program. This includes installation and monitoring of surface and subsurface strong motion instruments at four locations in the Delta, field and laboratory testing of soils at locations where surface and subsurface seismographs were installed, sponsored research on the dynamic response characteristics of organic soils, and additional dynamic response analysis.

Many of the monitoring elements proposed in the "Habitat and Mitigation Monitoring Plan," Appendix E, are currently performed by DWR's Central District in conjunction with DFG in administering the Subventions and Special Programs Projects. Documentation for participation in the AB360 Program includes habitat assessments in areas where levee work may occur. DWR's Central District has begun compiling this data on a GIS database. In addition, monitoring for success of mitigation will likely be required by many individual permits for levee construction and maintenance. As well, monitoring to assess dredge activity impacts will likely be required by permits for dredging.

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Appendix A

Levee Standard

Monitoring Plan

Objective: To monitor levee maintenance and improvements to assure base level flood protection for Delta levees is achieved.
Target: Improve and maintain levees to Public Law 84-99 Standards.

MONITORING

WHY

A base level of flood protection for Delta levees is necessary to reduce the risk to land use and associated economic activities, water supply, infrastructure, and the ecosystem from catastrophic breaching. The goal for base level protection is the Corps' PL-99 criteria for Delta levees. Once achieved, the PL-99 criteria must be maintained. It is also important that in constructing and maintaining levees to the PL-99 standard, all applicable environmental requirements are met. This is addressed in Appendix E.

WHAT

In 1987, the Corps implemented eligibility guidelines specifically for nonproject levees in the Sacramento-San Joaquin Delta. These minimum guidelines are included as Attachment A. Proof that the levee system meets the required standard involves documenting the levee profile and performing representative cross sections to confirm minimum levee geometry. In addition to this documentation the Corps requires inspections of facilities similar to those required under the State's HMP compliance program. The inspections will identify whether vegetation removal is necessary, if there are burrowing rodents, evidence of erosion damage or seepage problems, and other potential impacts to levee integrity such as exotic species impacts.

CALFED Program participants should continue to update levee profile and cross sections to monitor compliance with applicable levee criteria. Proposed long term levee rehabilitation goals include monitoring for compliance with the Corps of Engineers PL-99 guidelines.

The following are proposed Levee Program monitoring tasks:

(1) Levee Profiles shall be updated to incorporate applicable NAVD 88 vertical datum protocols. (Reference Appendix F). Levee Profiles could continue to be run on a five year cycle.

(2) Cross Sections documenting achievement of PL-99 geometry criteria shall be done in intervals no greater than one every 500 feet.

(3) Inspections shall be performed to monitor the quality of levee maintenance. Inspection performance standards should include PL-99 rating criteria.

(4) Bathymetric surveys shall be done to document undercutting of the water side levee slopes in problem areas that have been identified by consulting district engineers.

(5) DWR would continue to keep current profile and cross section drawings. A GIS database could be developed and maintained with adequate funding.

WHEN and WHERE

Monitoring for levee cross section compliance and quality of maintenance shall be done following completion of any levee improvement projects at the location work is performed or at least annually. Levee profiles and bathymetric surveys shall be run on a five-year cycle. Additional inspections for all items shall occur following a special event such as a flood that may impact levee integrity or in special problem areas as needed.

HOW

All levee cross section geometry surveys should be tied to a common horizontal and vertical datum. CMARP should conduct a comprehensive critique of available mapping technologies to assess the optimal combination of technologies that meet a defined standards of survey specifications and minimizes costs to the program.

Several new and competing technologies should be evaluated in tandem with traditional photogammetric and hydrographic surveying techniques: these new technologies are (1) multi-beam bathymetric mapping and (2) Light Detection and Ranging (LIDAR).

(1) High-resolution multibeam mapping systems typically are hull-mounted sonar arrays that collect bathymetric soundings with a series of electronically formed receive beams precisely pointed at a swath of angles away from the vertical. Some of these systems also can record the absolute amount of sound back-scattered to the array providing a backscatter map. Survey control of the ship's position is determined by both an inertial navigation system and dual differential GPS. Typically a team of scientists processes the multibeam data while at sea. Final data editing, compilation, mosaicking, and plotting are completed within a day of the end of a cruise. Data processing includes: editing navigation, removing spurious bathymetry and backscatter data, correcting water-refraction errors, gridding and mosaicking the imagery, and compiling the final map.

The final maps of bathymetry and backscatter are readily transferred to a GIS for various CMARP related analyses and compilations.

(2) The Army Corps of Engineers has developed an airborne laser-based mapping system called SHOALS that uses LIDAR technology with the reflective and transmissive properties of the ground and water to gather high-density survey data. When a light beam hits the ground, the energy is reflected, in part, back to the airborne system: when a light beam hits a column of water, part of the energy is reflected off the surface and the rest, unless absorbed by particles in the water, is transmitted through the column. Using this principle, SHOALS fires a laser into the water, where a significant amount of energy from the infrared beam is reflected off the surface and detected by receivers in the helicopter. The blue-green laser penetrates the surface and reflects off the channel floor. A computer calculates the depth from the time interval between the two reflected energy readings. Reflection, scattering, absorption, and refraction all combine to limit the strength of the bottom return and therefore the system's maximum detectable depth. This depth is a function of water clarity, generally about three times the Secchi depth. SHOALS products are readily transferred to GIS systems for contour maps, channel-levee projections, volumetric computations, and levee structure assessments.

RESEARCH

One important goal of CMARP is to reduce areas of scientific uncertainty affecting the achievement of CALFED management goals. Areas of research are to be prioritized by assessing the most serious impediments to implementing the CALFED program elements. Dredging and the placement of dredged materials are very important to success of the Levee program as well as to the ERPP program and possibly water supply reliability. Currently the dredge permitting process is hampered by lack of scientific information on sediment characterization and many permits require extensive monitoring. The CVRWQCB has indicated that it may be able to wave monitoring requirements in areas where reliable sediment data is available. Access to a GIS sediment characterization database would greatly simplify the permitting process.

A large component of the database creation would be an inventory of existing programs to identify information gaps, a task that is already required to prepare the overall CMARP program. A specific focus on the collection of information and filling of information gaps to create a GIS sediment characterization database would be consistent with the goals of the CMARP and would greatly aid the achievement of the Levee Program goals as well as other CALFED program goals.

Attachment A: PL84-99 Delta Specific Standard

Appendix B

Delta Levee Subsidence Control

Monitoring Plan

Objective: Reduce the risk to levee system integrity from subsidence.
Target: Reduce, eliminate, or reverse subsidence adjacent to affected levees.

MONITORING

WHY

Levee integrity can be negatively affected by levee subsidence/setlement or the subsidence of land immediately adjacent to the levee. Monitoring will provide important information that can be used to develop efficient and timely design solutions for levee rehabilitation and maintenance. Monitoring and research will help quantify the risk to the levee system from subsidence.

PROJECT/ISLAND SPECIFIC MONITORING

WHAT

1) Land surface elevation.
2) Subsidence rates, including levee subsidence / settlement and adjacent land subsidence.
3) Horizontal extent of peat and organic soils.
4) Vertical extent of peat and organic soils, (layer thickness).
5) Ground water levels / elevations.
6) Peat and organic soil properties including,
    Gradation.
    Organic matter content.
    Moisture content.
    Void ratio.
    Compressibility
7) Sea level rise.

WHEN and WHERE

1) & 2) Land Surface Elevation and Subsidence / Settlement rates:

Levees.
Land surface elevation data including the levee cross section and interior land surface up to 500 ft from the levee should be obtained on 1000 ft spacing. Initial surveys information should be obtained during the levee rehabilitation planning and design stage concurrent with design cross section surveying. Monuments should be established at regular intervals. Subsequent section surveys could be obtained at intervals from 3 to 24 months depending on subsidence / settlement rates. Subsidence and settlement rates can be determined from the multiple surveys.

Islands

Whole island elevation data could be obtained along 2 to 5 orthogonal traverses for those islands scheduled for rehabilitation within 5 years, at risk based on preliminary evaluations, or of significant importance to the public. Monuments should be established at regular intervals. Subsequent section surveys could be obtained at intervals from 3 to 24 months depending on subsidence rates. Subsidence rates can be determined from the multiple surveys.

3) & 4) Horizontal and vertical extent of peat and organic soils

Surface peat and organic soil exposures should be mapped to provide up to date information on the areal extent of these deposits. From this mapping and existing information, preliminary subsidence control target areas can be identified. Sample test results would be used to support the mapping of the islands surface deposits.

Along the levee survey sections and island traverses, near surface material should be sampled and tested to determine their classification, gradation and organic matter content. Samples should be obtained on 200 ft to 2000 ft horizontal spacings and at 3 ft to 5 ft vertical intervals, between 0 and 10 ft below the ground surface . Samples should be obtained during the levee rehabilitation planning and design stage concurrent and coincident with design cross section surveys. Subsequent material sampling and testing could be performed at intervals from 5 to 10 years depending on observed subsidence.

In addition to the shallow sampling, deep (50 to 100 ft) explorations should be accomplished to confirm and supplement the existing information on peat and organic soil layer thickness. Deep explorations, (drilling, sampling and testing), will typically be accomplished during the normal course of levee design and evaluation. The subsurface information obtained for the geotechnical design can also be used for subsidence monitoring.

Interior island peat and organic soil layer thickness could be accomplished along the whole island traverses and can be obtained quickly and easily with exploratory drilling or cone penetrometer testing (CPT). Exploration locations should be spaced about every 5000 ft.

5) Ground water levels / elevations.

Ground water levels can be monitored by recording water levels in existing open ditches and with new shallow observation wells. It may only be necessary to construct observation wells occasionally and at very wide spacings to obtain the information necessary to fully evaluate subsidence. Observation wells should be constructed along the island ground surface elevation traverses at intervals of about 5000 ft.

6) Peat and organic soil properties.

Along the levee survey sections, materials should be sampled and tested to determine their classification, gradation, organic matter content, moisture content, void ratio, and consolidation characteristics / compressibility. This information can be combined with observation to predict and evaluate levee performance. Undisturbed samples should be obtained on 200 ft to 2000 ft horizontal spacings and at 3 ft to 5 ft vertical intervals, between 0 and 50 ft below the ground surface. Samples should be obtained during the levee rehabilitation planning and design stage concurrent and coincident with design cross section surveys. Subsequent material sampling and testing could be performed at intervals from 5 to 10 years depending on observed subsidence.

7) Sea level rise.

Sea level rise should be monitored to differentiate the effect of sea level rise from the effects of subsidence.

COSTS AND TIME FRAME

The costs of subsidence monitoring would be included in specific island projects. It is estimated the monitoring would be amount to about 1 to 3 percent of the project construction cost. Subsidence monitoring would coincide with project schedules and the overall Levee System Integrity Program schedule.

DELTA WIDE MONITORING

WHAT

1) Land surface elevations.
2) Subsidence rates and changes in elevation.

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WHEN AND WHERE

Initially, ground surface elevation data should be obtained for the entire Delta. Ground surface elevation data for wide spread areas of the Delta have not been updated since the 1976/78 USGS topographic maps were published. Up to date information would be beneficial in identifying new subsidence problem areas that may have developed and revising existing subsidence control target area maps. Updated surveys, with a 0.3 ft plus or minus accuracy, should be obtained on approximately 20 year intervals.

COSTS and TIME FRAME

A Delta ground surface elevation contour map, showing 2 ft. contour interval, would take 36 to 48 months to produce and would cost approximately 14 million dollars.

RESEARCH

The causes of levee and interior island subsidence have been determined. Research should focus on evaluating the efficiency of the remedial or corrective measures. The most promising remedial measures for correcting oxidation induced subsidence include, capping the peat and organic soils with mineral soil, saturating or inundating the peat and organic soils, (permanent shallow flooding), and bio-accretion methods. Subsidence control measures should be included and "tested" as part of the base level levee rehabilitation projects. Information gathering and assessment will be most efficient and economical if subsidence research and levee monitoring are carried out concurrently and cooperatively.

LINKAGES

A great deal of CALFED Program work will require horizontal and vertical control. An single base map/control is critical. Common Programs', implementation, research and monitoring can be successfully linked only if there is a common point of reference. Individual Program may not be able to justify the expense of obtaining Delta wide coverage, but together the distributed costs are reasonable.

Appendix C

Emergency Management and Response

Monitoring Plan

Objective: Enhance existing emergency management response capabilities in order to protect critical Delta resources in the event of a disaster.
Target: To support emergency planning, response, and recovery in the Sacramento-San Joaquin Delta.

WHY

Levee failures in the Delta can threaten lives, public infrastructure, the ecosystem, and other public benefits. Strategies to achieve sufficient emergency response capabilities include the efficient use of agency staff for prompt response to events and clear delineation of responsibilities and tasks to provide the maximum use of available resources.

WHAT

The California Water Code, Section 128 provides that in a time of extraordinary stress or disaster, DWR may perform work or take action before, during, or after storms, floods, or watershed damage to avert, alleviate, or mitigate damage. Furthermore, *Government Code, Section 8607* provides that all State agencies must use the Standardized Emergency Management System (SEMS) for multiple-jurisdiction or multiple-agency response. *California Code of Regulations, Title 19, Section 2405* provides that all emergency response agencies must use an Incident Command System (ICS) for field level response. The *Governor□s Flood Emergency Action Team, Final Report,* State of California The Resources Agency, May 10, 1997, and *Flood Preparedness Guide for Levee Maintaining Agencies,* State of California Office of Emergency Services, November 21, 1997 give further guidance for emergency response.

The majority of the Sacramento-San Joaquin Delta levees are non-federal or "local" levees. These levees are the direct responsibility of the local levee maintaining agencies (LMA) for maintenance, improvement, operation, repair, and rehabilitation. LMA programs are supported by State funding under the Delta Levees Program. The Corps of Engineers also supports emergency response for local levees that protect populated areas or public infrastructure and rehabilitation of certain local levees that pre-qualify under Corps criteria. Flood fighting on levees is the primary responsibility of LMA's. If a flood fight exceeds the capability of an LMA, or if communities are threatened, the responsible city or county will assist with the flood fight.

In coordination with LMA's and/or representative cities and/or counties, DWR may provide flood fighting assistance in conformance with SEMS and established interagency protocols. DWR's flood fighting assistance for the Delta may include, but is not limited to:

Coordinating and providing information related to the status of flood emergency response
Coordinating with LMA's for acquisition of flood fighting assistance through mutual aid resources including the California Conservation Corps, the California Department of Forestry, and the California Youth Authority
Procuring and dispatching flood fighting materials
Coordinating levee inspections and high water monitoring and staking
Providing engineering and technical levee assessment
Providing environmental assessment
Disseminating data and information
Providing Delta Levee Program funding assistance
Providing coordination for U.S. Army Corps of Engineers funding and assistance under Public Law 84-99

A master checklist should be developed to assess the readiness of the appropriate agencies to provide for emergency response and the status of ongoing training programs.

WHEN and WHERE

Emergency response procedures and protocol are reviewed on a continual basis with the Office of Emergency Services and other emergency response agencies including, but not limited to, levee maintaining agencies, U.S. Army Corps of Engineers, various mutual aid assistance organizations and environmental agencies, to ensure effective emergency response coordination.

In addition, the above-mentioned master checklist should be completed no less than yearly to assess the overall level of emergency response readiness.

LINKAGES

Senate Bill 1841 was passed by the legislature and made effective January 1, 1993 (*Section 8607* of the *Government Code*). The statue directed the Governors Office of Emergency Services, in coordination with other state agencies and interested local emergency management agencies to establish the Standardized Emergency Management System. As a result, OES oversees and maintains operations of SEMS. OES has developed a SEMS Maintenance System to address the need for changes. The three-tiered system encompasses an Advisory Board, Technical Group, and Mutual Aid Regional Advisory Committees (MARACs). Collectively, these multi-agency groups ensure changes are made to the system when necessary. The groups are comprised of representatives from all disciplines involved in emergency response.

In an emergency, SEMS facilitates interagency cooperation and the efficient flow of resources and information between all field, local, county, regional and State response agencies within the State. OES oversees management of the Response Information Management System (RIMS) to assist to accomplishing this goal. DWR is the State's link to the U.S. Army Corps of Engineers for emergency assistance under Public Law 84-99.

Appendix D

Delta Levee Seismic Risk Assessment

Monitoring Plan

by:
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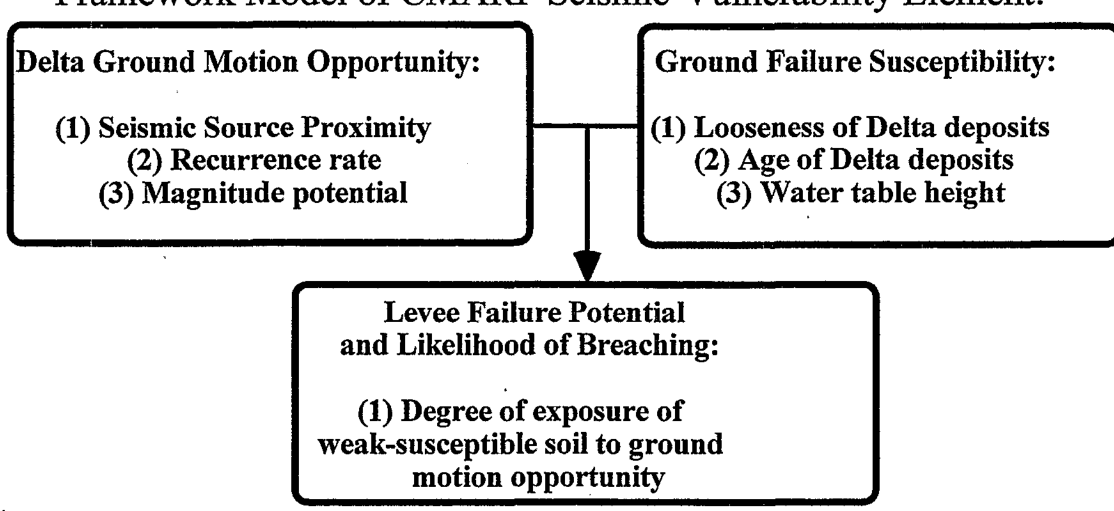
Dr. Arthur McGarr, Research Geophysicis, US Geological Survey
Mr. Michael Driller, Geotechnical Engineer, Dept. Water Resources

Objective: Characterize the seismic hazard to the levees with a view towards reducing breaching potential and assessing mitigation strategies.

Target: Minimize and mitigate the impact of seismic loading on levees through: [1] reduction of uncertainties surrounding seismic sources near the west Delta; [2] monitoring of seismicity; [3] GIS mapping of probabilistic ground shaking (ground motion opportunity), incorporating non-linear effects of soft and organic soils; [4] GIS mapping of ground failure susceptibility of levees; [5] GIS mapping of ground failure potential of levees based on 1, 3 and 4; [6] identification of critically vulnerable islands and assessment of the potentially beneficial impacts of restoration efforts on seismic vulnerability.

Framework Model of CMARP Seismic-Vulnerability Element:



WHY:

Catastrophic breaching of Delta levees during earthquakes will have an adverse impact on island use and economic activities; water-conveyance, -quality, and -supply; and ecosystem-restoration efforts. Catastrophic breaching may be a life-hazard, as well. Monitoring and research will provide important information for characterization of ground motion potential and levee fragility. Monitoring and research will help quantify potential for ground failure during earthquakes and identify stretches of levee most susceptible to breaching. Research will provide the framework-dataset to evaluate hazard mitigation efforts and the impact of restoration efforts on seismic vulnerability. An improved seismic hazard model, developed through these efforts, will serve as a *formal risk evaluation tool* for planners, public agencies, advocates for private concerns and politicians to weigh potential loss of life and property when considering long-term improvements to the Delta system.

DELTA-WIDE MONITORING AND RESEARCH

WHAT:

(1) Seismic-source characterization.

(2) Monitoring ground motions in the Delta.

(3) Mapping of probabilistic ground shaking, incorporating site effects including non-linear response of soil and peat.

(4) Mapping of ground failure susceptibility of levees.

(5) Mapping of ground failure potential of levees.

(6) Identification of critically vulnerable zones, assessment of restoration efforts.

WHEN, WHERE, HOW:

(1) Seismic-source characterization:

A generic Coast Range-Sierra Block (CRSB) fault model (sometimes termed Coast Range Central Valley fault, CRCV) has been assumed in previous and current evaluations of probabilistic ground motions in the Delta, but no positive evidence for the presence of blind thrust faults similar in style and rate of activity to those in Coalinga-Kettleman Hills region has yet been documented in the Delta. A systematic evaluation of the CRSB is needed to assess whether the structure is present in the Delta region. Because the presence of the CRSB would lead to predictions of a higher density of levee failures, additional work to evaluate evidence for and against the CRSB model is critical to reduce uncertainty about the likelihood of a catastrophic levee failure due to large, infrequent earthquakes.

There is significant uncertainty about the orientation and sense of slip on the Pittsburg-Kirby Hills fault zone (PKHFZ), which is the source of persistent background seismicity in the western part of the Delta near Pittsburg. The PKHFZ has been the focus of several recent USGS studies (BASIX-I,II,III) and represents the easternmost strike-slip fault in the San Andreas fault system. Seismic reflection profiling across this structure reveals a complex zone of faulting and folding, with strong evidence for Holocene faulting. Seismic reflection and seismicity studies document that the PKHFZ is both deep (20-25 km) and abundant, with numerous $M>3.0$ events in the region. Historic seismicity also indicates that this structure probably has the potential for a $M\geq6.0$.

The timing of contractional deformation of the crust underlying the Delta and the magnitudes of modern crustal deformation rates are only broadly constrained at present, and have significant uncertainties. Additional stratigraphic and structural analysis, particularly by systematically evaluating deformation of young stratigraphic markers visible in seismic reflection data, can reduce uncertainty about fault slip rates, which in turn will reduce uncertainty about earthquake return periods. The down-dip geometry of blind thrust faults beneath folds in the western Delta region has not been fully evaluated to determine which structures are most likely to extend to the base of the seismogenic crust, and thus be potential independent seismic sources. Improved constraints on down dip fault geometry are also essential for detailed and site-specific estimation of ground motions.

Identified monitoring and research tasks:

* New intermediate (1-2 km) and high-resolution (50-100 m depth penetration) seismic reflection data should be collected across the strike of the CRSB by conventional onshore- and marine-seismic reflection profiling techniques. Offshore survey lines will navigate Delta channels crossing the CRSB structure to image buried fault structures. The seismic reflection data would be augmented by analysis of existing gravity and aeromagnetic data. Together, these data sets would allow for a comprehensive analysis of fault geometry's and possibly the relative timing of fault slip and basement deformation.

* Portable microseismicity network arrays should be deployed in the Delta and eastern edge of the coast range to locate hypocenters and fault mechanisms based on analysis of first arrivals.

* Quantify expected maximum earthquake magnitudes and recurrence intervals for the earthquake sources.

(2) Monitoring ground motions in the Delta.

Earthquake recording instruments exist in several locations in the Delta. Most of the instruments are maintained by the Department of Water Resources. Some of this equipment is old and needs to be updated to modern digital strong motion recorders. In addition, some instruments need to be relocated. Results of this information will be used to measure the dynamic response characteristics of the Delta soils and calibrate the GIS strong motion models developed for the Delta.

Identified monitoring and research tasks:

* Modernize existing recorders.

* Relocate selected existing recorders.

* Identify new sites for free-field, levee crest, and downhole deployments.

* Locate portable microseismicity network arrays (see above).

* Existing Northern California stations near the Delta should be augmented by a downhole seismograph to increase array sensitivity, and avoid high levels of surface noise. Currently DWR has 4 downhole seismometer arrays.

(3) Mapping of probabilistic ground shaking, incorporating non-linearity effects of Delta soils and representative attenuation characteristics of motions for the Delta region.

Mapping ground shaking potential from known seismic sources, and those recommended for further investigation, above, is needed to better estimate levels of ground motion in the Delta. Thrust earthquakes occurring along the western boundary of the Central Valley pose a great hazard to the levee system of the Delta area. Two recent examples of such events are the magnitude 6.7 1983 Coalinga and the magnitude 6.2 1985 Kettleman Hills earthquakes. At the present time, the expected ground motions from thrust events on the Coast Ranges-Central Valley boundary are relatively poorly known, although regressions determined from motions recorded in these and other thrust events (Campbell and Bozorgnia, 1994; Boore et al., 1997) indicate that thrust earthquakes radiate larger accelerations than strike-slip events of similar magnitude.

Rock attenuation relationships developed for thrust events must be scaled for use in mapping Delta soil response to strong motions. Non-linear soil response of the Delta to upwardly propagating rock motion will be modeled by one-dimensional ground response analysis using shear modulus and damping data sampled from the delta (e.g. SHAKE91 -

equivalent linear approach) for a grid of Delta sites and site properties. These results will be used to map 'free field' peak acceleration, velocity, spectral accelerations at frequencies of interest, and.Arias intensity.

One significant uncertainty in ground response analyses of the Delta is the response of peat. Limited research on Sherman Island peat (Boulanger, et al. 1997) suggests that peat soil have modulus and damping characteristics comparable to high plasticity clays (PI of 100-200) and can be modeled as such. Further studies, from Sherman Island samples and other sites, should be conducted to refine the dynamic response characteristics of peat.

Identified monitoring and research tasks:

* Using Coalinga and Southern California recordings, determine new suitable attenuation relationships for near-Delta thrust earthquakes, incorporating seismic energy focusing associated with dipping-fault systems.

* Perform soil dynamic-property strain-dependent ground response analysis.

* Map probabilistic ground shaking potential for Delta soils.

* Further current studies of dynamic strain-dependent properties of peat.

(4) Mapping of ground failure susceptibility of levees and native soils founding levees.

Delta levees are susceptible to earthquake-induced breaching from dynamic slope failure, inertially-driven cracking, levee liquefaction, and bearing capacity failure in liquefied native soils. In the delta, soils susceptible to liquefaction are present both beneath and within many levees.

Liquefaction of sands down to about 50 feet has been known to cause significant surface effects. Thus, the distribution of liquefiable sands buried beneath the peat is a critical objective of any subsurface mapping investigation. In the Delta, Atwater (1982) has shown that alluvial fans, sand dunes, abandoned distributary river channels, and floodplains are the primary geologic environments responsible for buried sand layers in the Delta. Further geophysical, geological and geotechnical studies are required to define the distribution and degree of susceptibility of these soils. A large volume of geotechnical and geological data has already been collected along Delta levees and would serve as the principal dataset for the mapping effort. Much of this data has been collected by government agencies and private engineering firms. Geophysical techniques, like ground penetrating radar, will be used to map the geometry of buried river channels and alluvial fans susceptible to liquefaction. A digital elevation/bathymetric model developed for datum control will be used to model cross-sections for modeling inertialdisplacement during earthquakes. Thus, a linkage exists between datum control and seismic vulnerability tasks for the need for a comprehensive topographic survey and digital elevation model for the delta levees and channels.

Identified monitoring and research tasks:

* Compile existing surficial geologic, topographic and soils data, subsurface geotechnical data, and historical records of earthquake-induced liquefaction, as needed, to characterize the liquefaction susceptibility of deposits in the Delta.

* New data acquisition: Cone Penetration Testing (CPT) performed for CMARP subsidence control (see attached element) to acquire new data on peats directly links to this element. New projects with soil boring data collected in the Delta by governmental agencies and private entities, with their approval, should be integrated into this dataset.

* Using these data, fully integrated, GIS-based models (maps and cross sections) of Quaternary geology will be developed. Mapping will consist of (1) interpretation of existing geologic and soils maps, (2) inspection of topographic maps, aerial photography, and early maps of the Delta, (3) DWR, USACE, and industry geotechnical borings that show the engineering geologic properties of subsurface materials, (4) construction of local Quaternary stratigraphic columns, with age estimates and correlation charts, and (5) reconnaissance-level ground penetrating radar and in situ field investigations. These data layers will be used in predicting depths and thicknesses of potentially liquefiable deposits. Units of greatest relevance to liquefaction hazard assessments are typically sandy Holocene (less than 10,000 years old) deposits.

(5) Mapping of ground failure potential of levees.

The potential for liquefaction-induced permanent ground deformation is highly dependent on the strength and duration of ground motions. Thus, improved seismic source models, above, and the resulting predictions of strong ground shaking, should be fully incorporated into evaluations of liquefaction potential and site response. A GIS based assessment of ground failure potential is conducted by layering maps of ground motion potential and ground failure susceptibility, and incorporating existing models of cyclic stress and Arias intensity relations with liquefaction susceptibility of soil.

Identified monitoring and research tasks:

* Map ground failure potential using data layers from tasks 1,3,4.

(6) Identification of critically vulnerable zones, assessment of restoration efforts.

A complete evaluation of risk (i.e., loss of life and property, economic impacts from disruption to the Delta levee system, etc.) from seismic hazards to the Delta system should be performed that incorporates GIS layers of tasks 1,3,4, and 5. A severity index of liquefaction potential, based on the thickness of the predicted liquefied soil mass can be used to rank relative breaching potential of island levees. Zones should be identified and ranked by degree of breaching potential and assessed for the likely impacts of breaching to land use and economic activities; water conveyance within and through the Delta; and ecosystem restoration efforts. GIS layers 1,3,4,5 can be used as the framework for evaluating restoration efforts. For example, these layers can assist in identifying the best locations for island cutoff levees. These data layers can be used to assist in specifying design compaction effort for berms built behind levees, to reduce the potential for breaching.

Identified monitoring and research tasks:

* Rank breaching potential of Delta zones.

* Assess impact of breaching on land usage, water conveyance, and restoration efforts.

* Provide guidance on levee design for seismic stability.

Appendix E

Delta Levee Habitat Mitigation

Monitoring Plan

Objective: To meet applicable environmental requirements and to provide protection for wildlife and fisheries resources that reside in or pass through the Delta from impacts associated with implementation of the Long-Term Levee Protection Plan.

Target: To provide appropriate compensation for unavoidable environmental impacts associated with the Long Term Levee Protection Program.

MONITORING

WHY

The Long- Term Levee Protection Program includes measures to control subsidence, and reconstruct and maintain levees in the Delta. These measures will likely require significant amounts of fill material to be extracted from sources within and around the Delta, including dredging from Delta channels, and their placement on and around levees. This work may result in significant impacts to terrestrial and aquatic resources. Monitoring and research will help quantify these impacts and the performance of any necessary compensation.

WHAT

1) Site-specific impacts to terrestrial and aquatic habitat associated with levee improvements. This includes borrow, staging and stockpiling areas; and haul routes.
2) Cumulative impacts to terrestrial and aquatic habitat associated with levee improvements. This includes borrow, staging and stockpiling areas; and haul routes.
3) Water quality impacts associated with the dredging or deposition of material in Delta waterways.
4) Site-specific impacts to terrestrial and aquatic species of special concern associated with levee improvements. This includes borrow, staging and stockpiling areas; and haul routes.
5) Cumulative impacts to terrestrial and aquatic species of special concern associated with levee improvements. This includes borrow, staging and stockpiling areas; and haul routes.
6) Site-specific and cumulative benefits derived through compensatory mitigation for impacts associated with levee improvements, including mitigation banking.

WHEN AND WHERE

1), 4) and 6) Site specific impacts:

Pre- and post-project habitat and species information should be collected using appropriate methods at each site that sustains impact associated with levee improvements. This may include information from both aquatic and terrestrial sites where dredged, or other, material may be extracted and/or placed; and also from borrow, staging and stockpiling areas as well as haul routes. Information collected shall be entered into a GIS system for tracking purposes. Project site locations shall be referenced by both GPS coordinates and levee stationing points.

2), 5) and 6) Cumulative impacts:

Geo-referenced habitat and species information shall be evaluated using the GIS system to determine the potential cumulative impacts and benefits of levee improvement actions.

3) Water quality impacts:

Implementation of the CALFED solution will result in substantial improvements, maintenance and changes to Delta levees. Much of the work will involve the dredging and placement of dredged material in Delta waterways and on Delta islands. Water quality issues will develop associated with both in-channel sediment disturbance and re-suspension, and leachate from dredged or other material placed on upland sites for levee reinforcement and maintenance.

Water quality monitoring information needed for this element should be satisfied by the various components of the monitoring plan produced by the CMARP Water Quality Work Team.

Appendix F

Common Survey Standard

By: Darrel Ramus and Chris Neudeck; Kjeldsen, Sinnock & Neudeck, Inc.

In an effort to utilize a common coordinate system for mapping in the San Joaquin-Sacramento River Delta region, any projects funded in whole or part by any state or federal funding sources (PROJECT) will comply with the following minimum survey control standards:

1. **Primary Horizontal Control** for the PROJECT will reference the North American Datum 1983 (1992) epoch date 1997.30 as published by the National Geodetic Survey for the San Joaquin-Sacramento River Delta GPS/Vertical Project in July 1998, or the most recent NGS adjustment.

2. **Primary Vertical Control** for the PROJECT will reference the North American Vertical Datum 1988 (NAVD 88) as published by the National Geodetic Survey (NGS) for the San Joaquin-Sacramento River Delta GPS/Vertical Project in July 1998, or the most recent NGS adjustment.

3. **Secondary Horizontal Control** will tie local PROJECT site controls and all relevant published horizontal and/or vertical controls within the limits or encompassing the PROJECT and referenced to the Primary Horizontal Control described above. Relevant published horizontal and/or vertical controls include those published or maintained by NGS, U.S. Geological Survey (USGS), Army Corps of Engineers (COE), California Department of Water Resources (DWR), or local jurisdiction controls not included in the 1998 San Joaquin-Sacramento River Delta GPS/Vertical Project. The survey method and equipment accuracy specifications used to tie the Secondary Horizontal Control to the Primary Horizontal Control must be documented to allow determination of standard error residuals.

4. **Secondary Vertical Control** will tie local PROJECT site controls and all relevant published vertical benchmark controls within the limits or encompassing the PROJECT and referenced to the Primary Vertical Control described above. Relevant published vertical controls include those published by or maintained NGS, USGS, COE, DWR, or local jurisdiction benchmarks not included in the 1998 San Joaquin-Sacramento River Delta GPS/Vertical Project. The survey method and equipment accuracy specifications used to tie the Secondary Vertical Control to the Primary Vertical Control must be documented to allow determination of standard error residuals.

5. **The PROJECT Coordinate System** will depend on specific requirements, however, the final PROJECT coordinate system will be documented to clearly define the units and projection used relative to the Primary Horizontal Control. Units will typically be based on either the Meter or the U.S. Survey Foot. Projections will typically be based on the California Coordinate System of 1983 (CCS 83) by designated zone. If ground distances are shown, a PROJECT scale factor and origin must be provided to allow conversion to grid coordinates and distances.

6. **The PROJECT Vertical Datum** will depend on specific requirements, however, any historic or "local" vertical datum adopted for the PROJECT must be documented in relation to the 1998 San Joaquin-Sacramento River Delta GPS/Vertical Project. The method used to model or "datum shift" the PROJECT Vertical Datum from the Primary Vertical Control described above must be documented to show specific benchmarks held or modeling used. Depending upon the PROJECT requirements, such methods might include direct measurements and network adjustments, adoption of specific published benchmark historic elevations, and/or VERTCON and GEOID modeling. Many projects will likely need to reference benchmarks or legacy data established on the National Geodetic Vertical Datum of 1929 (NGVD 29). It will be necessary to establish whether legacy NGVD 29 data will be modeled to the NAVD 88 datum held for the Primary Vertical Control or vice versa.

7. **The PROJECT Control Summary** will include a tabular coordinate summary of all Primary and Secondary Horizontal and Vertical Controls surveyed relative to the 1998 San Joaquin-Sacramento River Delta GPS/Vertical Project control network (NAD 83 and NAVD 88 Datums), along with the final PROJECT coordinate values of the same control points. A brief description or table describing the final PROJECT datum, projection, units, control monuments held, survey methodology, survey equipment accuracy specifications, survey adjustments made, and standard error residuals will be provided with the control summary.

8.

Delta Levee Monitoring Protocol will include the minimum requirement to survey the centerline levee horizontal alignment, centerline levee vertical profile and levee cross sections at a predetermined interval along the alignment for the purpose of levee subsidence monitoring. Depending upon the specific PROJECT requirements, inventory field surveys of major physical features along the levee alignment, orthorectified digital photography, bathymetric channel surveys and topography mapping may be incorporated to monitor structures, embankments, erosion, seepage and vegetation. Topography mapping should meet specified National Mapping Accuracy Standards, or equivalent, and be based on at least one of the following methods: cross section modeling, digital terrain modeling (DTM) from breakline surveys, aerial photogrammetry derived contours and spot elevations, or other certified survey methods that achieve the minimum required accuracy for the purpose of levee subsidence monitoring. In all cases, specific field data used to model the topography mapping should be based on the final PROJECT Horizontal and Vertical Control and be retraceable in the field to allow independent data integrity checking.

9. **Linkages** The first seven steps should be followed for all survey tasks within the San Joaquin-Sacramento River Delta region to develop a common survey grade mapping database. This should streamline any follow-on modeling, planning, design, construction and monitoring activities and allow various projects to utilize existing mapping with a higher level of confidence

Please call Darrel G. Ramus, PLS or Christopher H. Neudeck @ (209) 946-0268 if you have any comments or suggested changes to this document.

Sincerely,

KJELDSEN, SINNOCK & NEUDECK, INC.